S-6/PHSH/CC-14/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

FOURTEENTH PAPER : CC – 14

Full Marks : 60 *Time* : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP—A

1. Answer *any* **six** of the following questions : 2×6=12

(a) Explain the analogy of black-body radiation with ideal gas.

(b) Mention the difference between Wien's distribution law and Rayleigh-Jeans law in relation with black body radiation.

(c) What is thermodynamic probability?

(d) What is Gibbs paradox?

(e) What is 'Fermi energy'? Does it depend on temperature?

(f) What do you mean by strongly degenerate Bose gas?

(g) At same temperature, which will exert greatest and least pressure — a gas obeying MB statistics or a gas of bosons or a gas of fermions?

(h) Show that at high temperatures the FD distribution reduces to MB distribution.

GROUP—B

There are *four* questions from Question No. 2 to Question No. 5. Answer either *(a)* **or** *(b)* from each question given below : 12×4=48

2. *(a)* (i) State the Planck's law of black body radiation. Deduce Rayleigh-Jeans law from Planck's law of black-body radiation.

(ii) What is radiation pressure? Show that the pressure due to diffuse black body radiation is one third of energy density of radiation.

(iii) Calculate the black-body temperature of sun from the following data : Stefan Constant = $1{\cdot}37 \times 10^{-12}$ cal/cm^2/s, solar constant = 2·3 cal/cm^2/min, radius of the sun = 7×10^{10} cm, distance between the sun and earth = $1{\cdot}5 \times 10^{11}$m

(2+2)+(1+4)+3=12

(OR)

(b) (i) State and prove Kirchhoff's law in relation with black-body radiation.

(ii) What is meant by diffuse radiation?

(iii) Write the Planck's quantum hypothesis.

(iv) A black-body of a temperature of 1646 K has wavelength corresponding to the maximum emission λ_m equal to 1·78 micron. Find the temperature of the moon (assumed to be a black-body) if λ_m for the moon is 14 micron.

(1+4)+2+2+3=12

3. *(a)* (i) What is phase space? Show that the volume in phase space corresponding to a discrete quantum state is h^3.

(ii) Derive the Maxwell velocity distribution law using MB statistics.

(iii) A system of distinguishable particles has two non-degenerate single particle energy states O and E. Show that at temperature $T = E/K_B \ln 2$, the probability of a particle occupying the excited state be half that occupying the ground state.

(2+2)+4+4=12

(OR)

(b) (i) State and prove Sackur-Tetrode equation.

(ii) Show that the partition function for a monoatomic ideal gas is given by

$$Z = \frac{V}{h^3}(2\pi m k_B T)^{\frac{3}{2}}$$

Where symbols have their usual meanings (consider MB statistics).

(iii) Distinguish between mathematical probability and thermodynamic probability.

(iv) What are the limitations of MB statistics?

(1+4)+3+2+2=12

4. (a) (i) Name the statistics (BE or FD) obeyed by each of the following particles; neutron, π-meson, photon, neutrino.

(ii) What do you understand by Bose Einstein condensation? Calculate the critical temperature at which the condensation will start.

(iii) Write the properties of liquid helium.

2+(2+5)+3=12

[Continued]

(OR)

(b) (i) Derive Planck's law of black-body radiation using Bose-Einstein statistics.

(ii) Show that maximum entropy of a photon gas is given by

$$S_{max} = \frac{4V\pi^2 K_B^4 T^3}{45\hbar^3 dc^3}$$

Where symbols have their usual meanings.

(iii) Discuss the difference between Fermi-Dirac and Bose-Einstein statistics.

5+5+2=12

5. (a) (i) Write the basic-assumptions of FD statistics. Derive the expression for Fermi-Dirac distribution law.

(ii) Show that for a two-dimensional electron gas, the number of electrons per unit area is given by

$$n = \frac{4\pi K_B T}{h^2} \ln\left(e^{\frac{E_F}{K_B T}} + 1\right)$$

(2+5)+5=12

[Turn Over]

(OR)

(b) (i) Write down the distribution law obeyed by electron gas and apply the same to derive Richardson-Dushman equation.

(ii) Show that if f is the FD distribution function, $-\frac{\partial f}{\partial E}$ is a maximum at Fermi level. Also show that $-\frac{\partial f}{\partial E}$ is symmetric about the Fermi level. (1+5)+(3+3)=12

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